Conceptual Design of the Pointing and Control for the Space Infrared Telescope Facility

Abdullah S. Aljabri

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, CA 91109

ABSTRACT

The Space Infrared Telescope Facility mission provides exciting pointing and control challenges. This paper describes the pointing and control subsystem (PCS) designed to meet these challenges. Cost, mass, performance and life-time drove the choice of the new orbit and the re-design of the telescope, spacecraft and the pointing and control subsystem. The PCS performs a number of key functions for the Observatory, including pointing to and holding inertial targets, tracking moving targets, performing prescribed motion patterns, maintaining pointing constraints and providing safe hold during failure. To attain the high precision demanded by the observatory the PCS relies on a sub-arcsecond star tracker and a 0.001 arcsecond resolution inertial reference unit. An affordable PCS is realized by locating the fine guidance sensor externally, utilizing a simple fault protection strategy, sharing the flight computer with the command and data handling (C&DH) subsystem, and employing a common team to develop the PCS and C&DH flight software.

1 INTRODUCTION

1.1 Background

The Space Infrared Telescope Facility (SIRTF) will be a one-meter-class, cryogenically cooled, astronomical observatory currently planned for launch around year **2001. The** SIRTF candidate design has undergone substantial changes including a new solar orbit and design modifications which reduce the development cost by more than half while retaining much of the fundamental scientific importance and promise of the original SIRTF. The new concept referred to as the Atlas SIRTF (as opposed to the previous Titan-launched SIRTF) has less than half the mass, is to be launched into solar orbit instead of the high earth orbit (HEO), and the mission life time is reduced from five to three years. The biggest changes in the pointing and control subsystem (PCS) concept are the removal of the fine guidance function from the cryogenic interior of the telescope and the use of a fixed in place of an articulated secondary mirror. The new concept mounts the external fine guidance sensor on the cryostat external shell and is supplemented by simple quadrilateral sensors within the instrument chamber for periodic internal to external alignment.

SIRTF is expected to be executed as a systems contract, with a planned 1997 new start, The descriptions of the observatory given here represent the current point design concept only, and are not meant to imply that these designs will be the ones to fly.

1.2 Science Objectives

SIRTF operating outside of the earth's atmosphere will obtain infrared observations which will enable scientists to:[1]

- Investigate the formation and evolution of galaxies, looking back in time into the early history of the universe.

- Study **in detail young** and **forming stars and their** interactions with their enveloping clouds of dust and gas.
- Study the chemical synthesis of the elements in supernovae in galaxies over 50 million light years away.
- Search for brown dwarfs which may constitute the missing mass whose gravitational influence is known but no direct evidence of the "dark matter" has been found.
- Examine the fossil records of our solar system from spectra of small cool bodies such as comets, asteroids and planetary satellites.
- Study the formation and evolution of other solar systems.

1.3 Science Instruments

Three science instruments are being developed to operate in a cryogenic environment at about 1.5" Kelvin. This environment is required to obtain the low instrument and telescope backgrounds necessary to detect faint astronomical signals.

The Infrared Array Camera (IRAC) is being designed to provide imaging and polarimetry over the wavelength range 1.8 to 27 micrometers. This instrument is being developed by a team led by Dr. G. Fazio at the Smithsonian Astrophysical Observatory.

The Infrared Spectrograph (IRS) is being designed to take medium resolution spectra of astrophysical targets over the wavelength range 4 to 200 micrometers. This instrument is being developed by a team led by Dr. T. Houck at Cornell University,

The Multiband Imaging Photometer for SIRTF (MIPS) will provide imaging, polarimetry, and large area mapping capabilities over the wavelength range 40 to 200 micrometers. This instrument is being developed by a team led by Dr. G. Rieke at the University of Arizona.

1.4 Mission Overview

The mission concept[3] is to launch SIRTF with just enough energy to escape Earth's gravity into a heliocentric orbit (hereafter referred to as a " solar orbit") with a small drift rate of about 0.1 AU per year away from the earth. The solar orbit was chosen over the previous HEO of 100,000 km altitude because it requires much less launch energy. The Atlas HAS launch vehicle, being considered for use on SIRTF, can place 2500 kg into solar orbit compared to only 1500 kg into HEO. Other advantages of the solar orbit are: it requires less cryogen because the thermal load from the earth is greatly reduced, the Earth/Moon avoidance constraint is removed and the pointing and fault protection functions are simplified because of the more benign and stable thermal environment.

Figure 1 from reference 3, shows the solar orbit in a rotating frame relative to the Sun-Earth line. The SIRTF solar orbit is more eccentric than the Earth orbit and consequently the observatory appears to move towards the Earth at perigee and away from the Earth at apogee. In order to maximize the sky coverage and minimize the size of the solar panel SIRTF uses a solar panel tilted at 20" from the telescope. The inset in Figure 1 shows that the telescope can be pointed from +5° through -45° relative to the ecliptic pole which gives about 40% sky coverage with the solar panel providing nominal power. Only 14.7% of the sky requires off-sun pointing, where the batteries are needed to supplement the solar panel power.

2 OBSERVATORY CONFIGURATION

Figure 2 shows the observatory in the launch configuration on top of the Atlas IIAS launch vehicle.

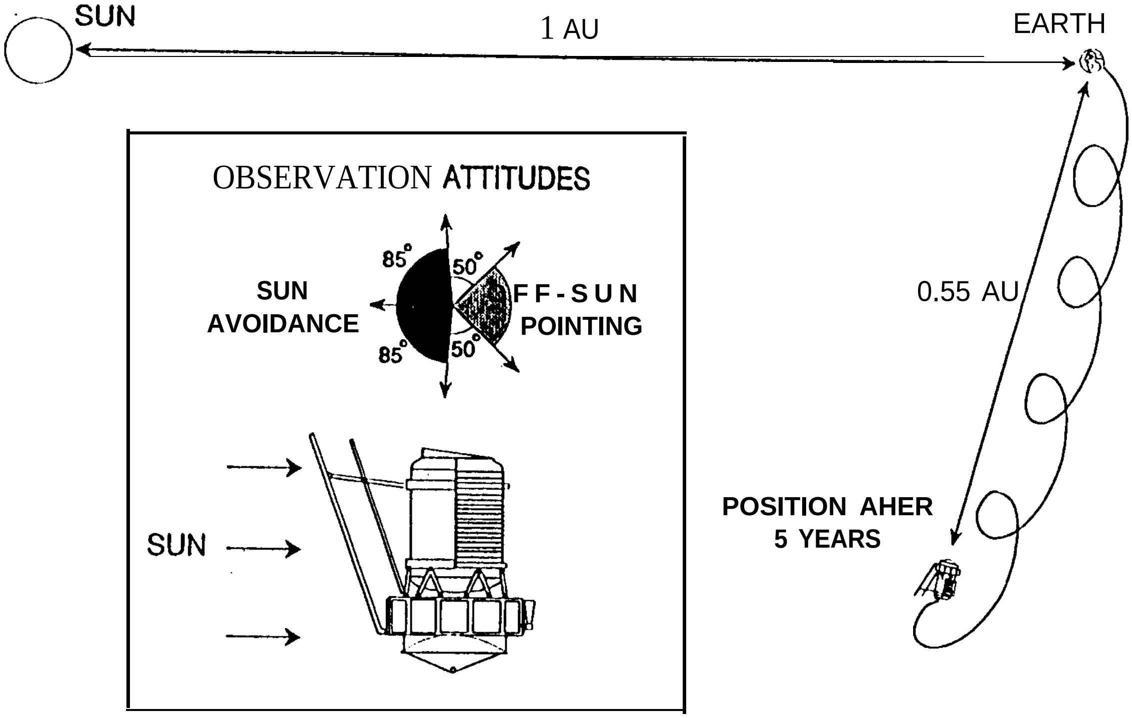

Figure 1. The Solar Orbit in a Rotating Frame Relative to the Sun-Earth line.

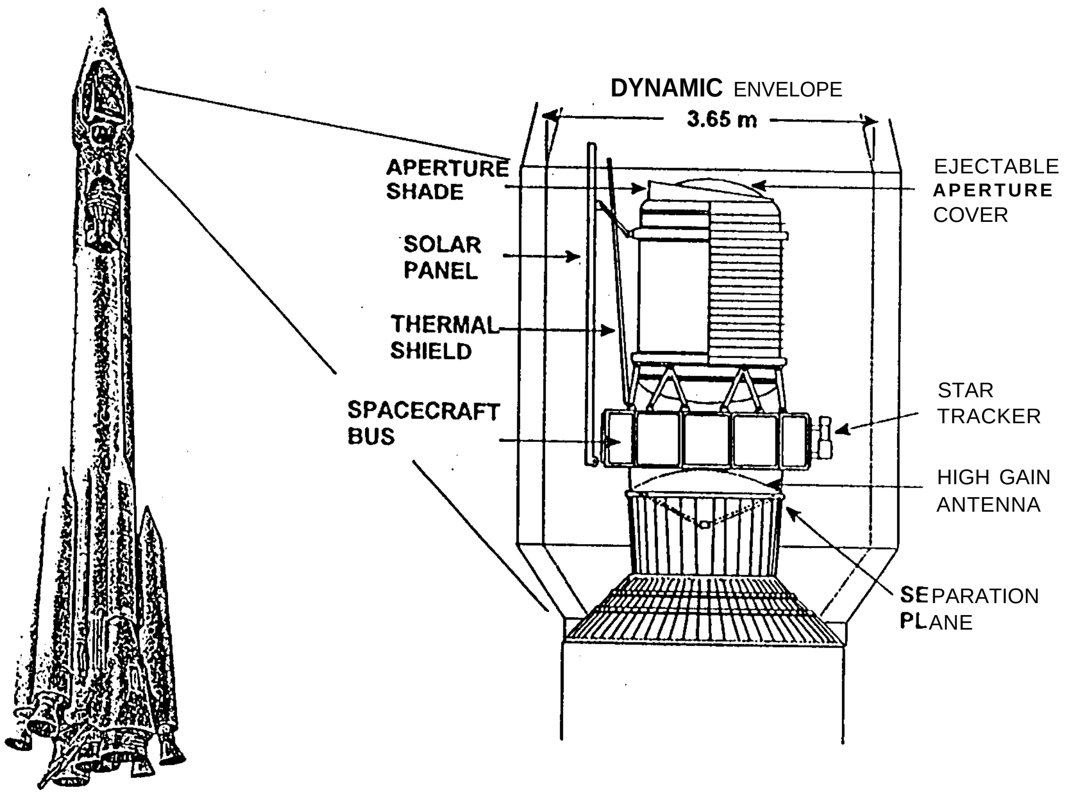

Figure 2. The SIRTF Observatory on the Atlas IIAS Launch Vehicle,

2.1 Telescope

The candidate design features a two-mirror Ritchey-Chretien telescope embedded in a 1000-liter superfluid helium dewar which provides a cryogenic lifetime of three years. The telescope employs a lightweight 85 cm diameter primary mirror and a fixed secondary. The primary f-ratio is f/1 .5, and the system f-ratio is f/12. The three science instruments and the quadrilateral sensors are located behind the primary mirror in the multiple instrument chamber (MIC)as illustrated in Figure 3. The total telescope mass is estimated to be 850 kg.

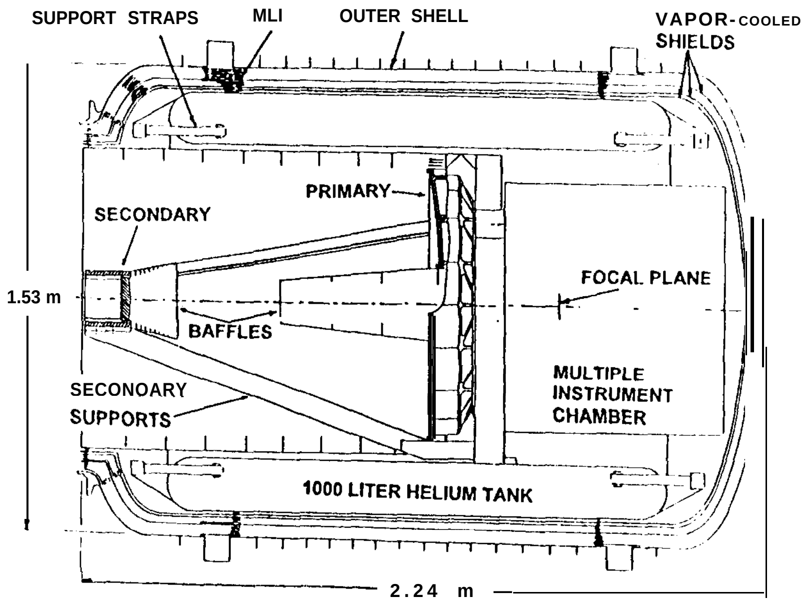

Figure 3. **The SIRTF Optical Telescope Assembly.**

2.2 Spacecraft

The main part of the spacecraft bus consists of a cylindrical module attached by struts to the bottom of the optical telescope assembly. The module contains twelve electronic bays on the perimeter while the center houses the four reaction wheels and the reaction control subsystem propellant tanks. The module is 2.2m in diameter and 0.6 meters high, A 1,47 m X band high gain antenna is attached to the bottom of the cylindrical module. A rectangular solar panel of 6.8 square meters area is located on the side of the telescope and is deployed once at the start of the mission to an angle of 20” away from the telescope boresight. A thermal shield, also a rectangular panel, is located between the solar panel and the telescope external shell and is likewise deployed. Two star trackers are located on the telescope side opposite the solar panel. The spacecraft wet mass is estimated to be 800 kg, and the average power consumption is estimated at 700 W.

3 PCS REQUIREMENTS

3.1 Pointing Accuracy

The observatory is required to be capable of placing an inertially fixed science target, referred to by its coordinates in the J2000 system, to within 3 arcsecond (1a radial) of the center of a specific IRS instrument array. This is the pointing accuracy levied on the PCS, although the requirements of instruments other than the IRS is 5 arcsecond. The roll angle accuracy is required to be within 3 degrees (1σ radial) for all instruments.

3.2 Target Peak-up Acquisition

The IRS at the shorter wavelengths requires anointing accuracy of 0.25 arcsecond (1 σ, radial) to reliably place a point source on the small spectrograph slit. Rather than levy that accuracy on the facility the IRS instrument itself is employed to assist in the fine pointing. Two PCS steps are needed to place the target on the slit. In the first step the PCS is required to place the target with an accuracy of 3 arcsecond on a specific IRS detector. This is the aforementioned pointing accuracy. The IRS instrument is then responsible for identifying the target and determining the offset required to place it in the center of the selected slit, This process is known as peak-up. The second PCS step repositions the line-of-sight (LOS) to within 0.25 arcsecond of the offset specified by the IRS peak-up detector. The repositioning motion is limited to 30 arcsecond or less. Therefore, the peak-up acquisition mode levies a 0.25 arcsecond relative motion requirement on the PCS without tightening the absolute knowledge requirement.

Peak-up is necessary not only to relieve the facility pointing requirement, but also because:

- There are regions where there is uncertainty in guide star and target coordinates.
- Newly found comets and asteroids may not have ephemerides better than a few arcsecond.
- No guide stars maybe available in molecular cloud complexes.

3.3 **Reposition Accuracy**

In some of the mapping functions, precise relative positioning of individual observations are required. Individual exposures are then stitched together into a map. The center-to-center spacings may be as small as 1.2 arcsecond with an accuracy of 0.25 arcsecond. This is the same requirement as the offset requirement needed to support the peak-up mode.

3,4 **Pointing Stability**

Pointing stability is a measure of the observatory jitter and directly affects the image quality, because it extends the point spread function over a larger area blurring the image. SIRTF is required to provide image quality such that 50% of the light from a point source is enclosed within a 5.8 cm diameter circle at 3.5 μm. To be compatible with this performance, the PCS is required to maintain a stability of 0.25 arcsecond over a thousand second interval. The time interval is a compromise, long to provide depth in sensitivity but not so long as to unduly stress the PCS design.

3.5 **Tracking**

A tracking capability is required for observing solar system objects. The pointing accuracy and stability must be maintained during tracking for rates up to 0.21 arcsecond per second. This rate which matches the rate of Halley's comet at a distance of 1 AU, is thought to be sufficient to cover most solar system objects. The ephemerides of many targets are known well enough to allow open loop tracking.

3.6 **Coverage**

SIRTF is required to have a greater than 99.5% probability of acquiring guide stars over the entire celestial sphere with performance emphasis in galactic poles and dark cloud regions. We assume the Hipparcos and Tycho guide star catalogs from the Hipparcos mission will be available for SIRTF. This allows the use of over 1,000,000 stars down to 11 magnitude with accuracy of 0.03 arcsecond and proper motion accurate to 0.03 arcsecond/year for the SIRTF mission time frame. This requirement drives the star tracker field-of-view (FOV).

3.7 **Reconstruction**

The absolute ground reconstructed pointing knowledge is required to be within 0,25 arcsecond (1 σ, radial) relative to field astrometric stars. This accuracy is chosen to allow comparison with data at other wavelengths and from different instruments.

3.8 **Maneuvers**

The slew and settle time requirements are tabulated in Figure 4.

SLEW ANGLE	SLEW/SETTLE TIME (Seconds)
1'	20
7'	42
1"	100
5°	205
180°	820

Figure 4. Slew and **Settle Time Requirements for SIRTF.**

4 PCS DESIGN AND INTEGRATION

4.1 Approach

The availability of accurate charge-coupled device (CCD) cameras, fast microprocessors, high density memory chips and the advent of robust and highly efficient star pattern recognition algorithms has made it possible to realize high performance spacecraft pointing systems. The challenge is to put together the available technology into an affordable package. The old SIRTF PCS concept, characterized by a fine guidance sensor (FGS) located within the cryogenic instrument chamber was prohibitively expensive to develop. The current approach is estimated to reduce cost by a factor of five. The following are the significant changes made to reduce costs.

- The FGS is located external to the telescope.
- A simple fault protection philosophy is utilized.
- The PCS and C&DH subsystem share the flight computer.
- A common team is used to develop the PCS and C&DH flight software.

4.1.1 Internal versus External Control

The most direct way to control the LOS is to place the reference fine guidance sensor (FGS), within the telescope at the focal plane. Because the sensor is in close proximity to the LOS and is in the same thermal environment as the instrument array pointing errors due to misalignment are minimized, When locating the FGS outside the dewer, however, significant pointing errors may be introduced by . distortions in the optical bench, external shell, external sensor mounting and distortions within the sensor. While the internal option is technically attractive, cost considerations make it prohibitive. It is estimated that it would cost over $100 million to develop an internal FGS. Additionally, heat emitted by any sensor in the cryogenically cooled telescope detracts from the observatory lifetime and requires additional resources to compensate for the loss.

Whereas in the original SIRTF design an internal FGS was crucial to meet pointing requirements, in the Atlas SIRTF concept an internal FGS is not essential, because the observatory operates in a more thermally benign environment and the stability requirements have been relaxed. The original requirements called for a stability of 0.15 arcsecond over an interval of 3600 seconds. The new requirements are a stability of 0.25 arcsecond over 1000 seconds. Preliminary analysis show that misalignment due to thermal distortions remain within requirements and allow the fine guidance function to be accomplished by an externally mounted star tracker unit (STU). This external tracker architecture remains a challenge although not as formidable as an internal FGS.

4.1.2 Fault Protection

SIRTF proposes a simple, inexpensive and yet effective fault protection system, The fault protection is designed to protect against two major categories of faults. The first is to detect problems with the PCS/C&DH computer's CPU, memory, or software, The second is to detect problems with the PCS hardware units. All critical PCS hardware components are redundant and cross-strapped. Algorithms for switching from one unit to another to obtain a complete functioning string are included, Upon occurrence of a fault condition the Observatory is commanded to enter the safe hold mode and await further commands from the ground, No attempt is made to autonomously perform fault isolation within any unit, but sufficient state-of-health data is obtained, so that the ground can perform the isolation.

4.1.3 Shared C&DH and PCS Flight Computer

In the past, it has been customary in spacecraft design for the PCS to have its own central processing unit (CPU), A trade study was conducted to examine the option of merging the PCS CPU with the C&DH CPU. The study showed that there are significant savings in mass, volume, power, and memory, in addition to improvements in CPU throughput, The current SIRTF design reflects this merger.

4.1.4 Combined PCS/C&DH Software Development Team

On SIRTF it is proposed to use one software development team for both PCS and C&DH, using the same software tools and one test-bed for flight software testing. The team will use one set of support equipment to support the integration and test laboratory (ITL) testing. The benefits are:

- Reduce management, administration and test-bed set up costs.
- One software architecture will be employed,
- Achieve better interface and design consistency between two dominating spacecraft subsystems.
- Promote the use of common modules (e.g. executive, hardware and software interface modules.)
- Support equipment and workforce cost reductions can be realized,

4.2 PCS Functions

In common with other JPL spacecraft, the PCS is required to:

- Determine spacecraft attitude.
- Provide attitude control.
- Perform reaction wheel desaturation.
- Detect failures and provide a "safe-hold" mode until ground operations can resolve anomalies.
- Determine the health status of subsystem hardware and software components.

In addition, for SIRTF the PCS must also provide the following functions;

- Maintain inertial hold for observations of long duration.
- Perform rapid large angle slews to acquire new targets.
- Make precise relative reposition motions.
- Ensure that pointing avoidance constraints are not violated; Boresight must not point to the sun.
- Calibrate the internal to external line of sight alignment,

4.3 **PCS Description**

The PCS block diagram is shown in Figure 5. There are five different types of sensors that estimate SIRTF attitude, rate measurements and the LOS alignment. These are:

- Two Star Tracker Units (STU).
- Two Fine Sun Sensors (FSS).
- Eight Coarse Sun Sensors (CSS).
- Two Quad Sensors (QS)
- One Inertial Reference Unit (IRU), internal redundancy provides two channels of attitude data.

There are two sets of attitude electronics, each consisting of a flight computer, power supply units, sensor and actuator interface electronics, and bus interface units. The computer is shared with, and resides withiin, the C&DH subsystem. An alternative is to have the two subsytems share a general purpose flight computer.

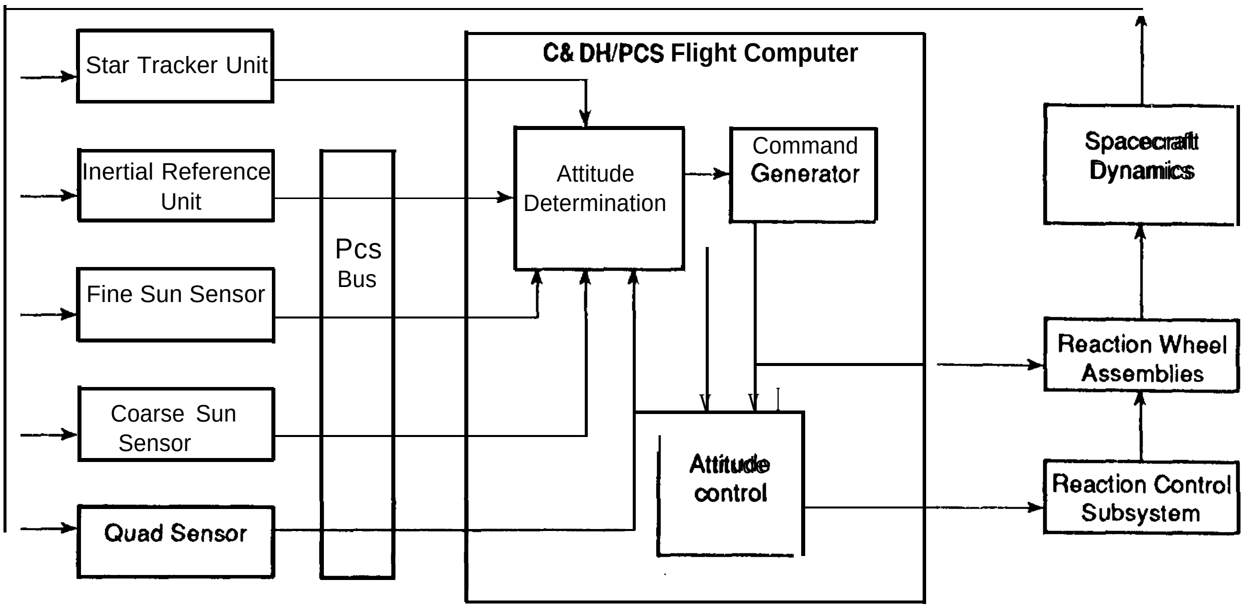

Figure 5. PCS Functional Block Diagram.

Two kinds of actuators are used on SIRTF. These are the Reaction Wheel Assemblies (RWA's), all four of which are in use normally, although three are sufficient to meet requirements, and one' nitrogen Reaction Control System (RCS) which has redundant plumbing, valves and thrusters, The RCS is used solely to desaturate the wheels.

The sensors and actuators, with the exception of the STU, communicate with the PCS/C&DH flight computer through a redundant serial data bus. The STU employs a dedicated interface to send the large CCD image data to the flight computer.

Three software blocks are shown in Figure 5. These include the command block, which determines the desired attitude and attitude rate, the attitude determination block, which estimates the current observatory orientation and rates, and the attitude control block, which generates the reaction wheel torque signals to control the observatory.

4.4 **Stability Error Budgets**

Pointing stability is defined as the' maximum variation of the angle between the actual and desired pointing direction over a time interval. The pointing stability for SIRTF is 0.25 arc second (1 σ) over a continuous period of 1000 seconds. It is convenient to partition the various contributors to the stability error sources into four categories as shown in Figure 6.

4.4,1 Star tracker Centroiding Resolution

The STU provides the low bandwidth position corrections. When maintaining attitude, the STU must be capable of determining perturbations of the position of the reference star of 0.16 arcsecond or greater. This means that the STU must detect shifts in the centroid of the star image of 0.16 arcsecond, which specifies the noise equivalent angle (NEA) for the tracker.

4.4.2 IRU Error

The IRU provides high bandwidth position corrections between STU updates. The IRU resolution is 0.001 arcsecond per pulse, However, the IRU accumulates drift rate and thermal distortion errors which are limited to 0.06 arcsecond for the 10 second duration between updates.

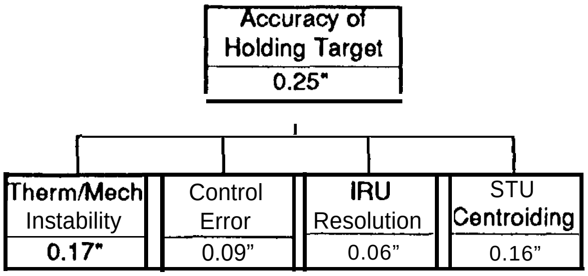

Figure 6. Pointing Stability Error Budget.

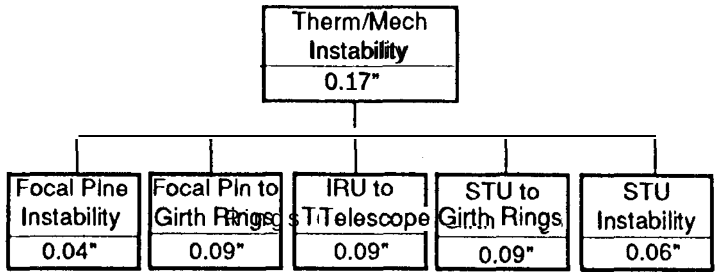

Figure 7 Structural Instability Error Budget,

4.4.3 Control System Error

The control system which maintains the position does so to an allocated accuracy of 0.09 arcsecond. The gyros and reaction wheels are continually operating in conformance with control laws that compensate for disturbances while maintaining the desired attitude. Included among the control error sources are the noise from gyros and reaction wheel disturbances. Other sources of error are internal torques from mechanisms with uncompensated momentum, cryogen slosh, and uncompensated structural modes.

Impact of Reaction Wheel Disturbances. The reaction wheel disturbances include (1) rotor imbalance due to a center of mass offset and/or a misalignment of the rotor principal axis of inertia relative to the rotor rotation axis, (2) noise of the ball bearings (3) motor imperfections consisting of cogging and torque ripple, and (4) bearing friction/stiction which will cause a disturbance during wheel reversal.

The effect of bearing friction/stiction during wheel speed reversals can be eliminated during observations by proper distribution of the angular momentum over the four wheels. This strategy has the added benefit of substantially reducing the effect of the cogging torque and torque ripple, because it keeps the wheels spinning in a speed regime where the effect of these disturbances is negligible.

Rigid body analysis show that the reaction wheels used on the TOPEX spacecraft will meet SIRTF specifications. As the SIRTF design matures and details of the structural components are known further, a study will be conducted to examine resonances in the structure that affect the line of sight stability.

4.4.4 Thermal/mechanical Instability

The focal plane location relative to the STU is calibrated prior to an observation. In-between quad sensor updates, the internal LOS and STU LOS distortion is budgeted at 0.17 arcsecond maximum for the 1000 second duration.

The thermal/mechanical instability is further broken down into five sources: the tracker instability, the tracker attachment instability, the external shell to the internal instrument chamber instability, the IRU mount to the telescope instability and the focal plane instability. The budget for these components is shown in Figure 7.

4.S PCS Modes

4.5.1 Sun Acquisition

After launch as soon as the upper stage of the launch vehicle is jettisoned, the PCS takes charge of the control of the spacecraft. Attitude determination is initiated using the coarse sun sensors, fine sun sensors and inertial reference unit. The first objective is to reduce observatory rates to zero and to acquire the sun. The sun sensors have sufficient coverage, as shown in Figure 8, to immediately acquire the sun and orient the observatory so that the solar panel is normal to the sun. The solar panel and thermal shield are then deployed.

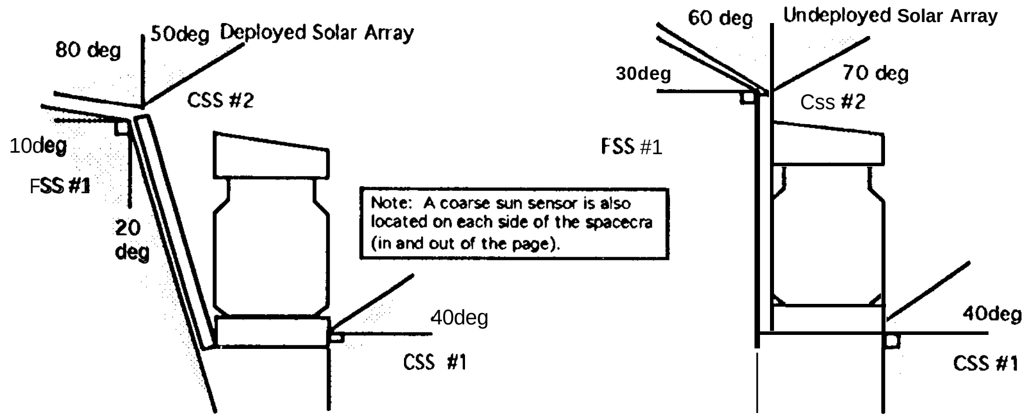

Figure 8. The Fine Sun Sensor and Coarse Sun Sensor Locations.

4.5.2 Attitude Initialization

Subsequent to sun acquisition, and to any failure which puts the observatory into safe hold, initial attitude determination is performed. To initialize attitude, the observatory is rotated slowly (1 mrad/s) about the sun line until the star tracker acquires at least two reference stars. A star catalog that contains the reference stars in an annulus strip of the celestial sphere for a given time of year is available on-board for attitude initialization, The full 3-axis absolute attitude is determined and broadcast throughout the spacecraft.

4.5.3 Attitude Determination

Once attitude initialization is complete, the telescope line of sight is calibrated relative to the externally mounted STU by observing a reference star with both the Quad Sensor and the STU. The STU provides the absolute attitude knowledge. Short term attitude knowledge changes are obtained by accumulating the gyro measurements (within the IRU) and compensating for known bias and misalignment errors. The IRU operates at 40 Hz. However, over time, round off errors, inaccuracies from the bias, scale factor and misalignment combine to ultimately degrade the knowledge accuracy. The STU absolute measurement is then required to bring the knowledge to the accuracy levels demanded, The STU normally operates at 10 Hz but the information update can take as long as 10 seconds for faint reference stars. Less frequently (period of days) internal to external alignments are performed to correct for thermal distortion.

4.5.4 Slew Maneuvering

All maneuvering, target acquisition, mapping, and solar object tracking commands are input to the command generator within the PCS, The command generator computes the quaternion to which the telescope must be maneuvered. It then determines the maneuver strategy that meets avoidance constraints and maximizes observation efficiency, It determines the acceleration, coast, and deceleration magnitudes that will minimize vibration and provide smooth vehicle motion. The reaction wheel assembly (RWA) torque signals are determined. During slews, STU inputs are not used, the observatory is under gyro (IRU) control only. The RWA slews the observatory according to the maneuver strategy, which depends on the maneuver angle. After a long maneuver, it may be necessary to use the STU to update the attitude, The PCS assesses if the target position is attained. If it is not, a new maneuvering strategy is developed and the process is repeated. Once the desired position has been attained, it is propagated using the IRU and STU.

Note that a maneuver consists of both slew and settling times; ‘the slew time is driven by wheel torque capabilities, while the settling time is driven by the control bandwidth and the flexibility and damping of the spacecraft structures.

4.5.5 Reaction whee Desaturation

All the SIRTF maneuvers are performed by reaction wheels which must be desaturated periodically. Upon desaturation command the actuation function is switched to the thrusters. Wheel angular velocities are set to predetermined values. As the wheels change speed, the appropriate thrusters are fired to keep the spacecraft attitude fixed, Thruster firing is not continuous but is done cyclically to allow sufficient time for the observatory to react to each firing. When all the wheels have achieved their commanded rates the attitude control function autonomously reverts to using the RWA'S for actuation Wheel desaturation can be performed autonomously as described above or commanded by the ground as a part of a sequence.

4.5.6 Safe Hold

The safe hold mode autonomously protects the Observatory when any single failure occurs in any subsystem. The Observatory is positioned to maintain solar array sun pointing and communication with the deep space network (DSN), without violating pointing constraints. The safe mode makes use of rate gyros, reaction wheels, coarse sun sensors and fine sun sensors. The safe hold mode is entered for PCS failures which lead to a loss of attitude knowledge.

S. HARDWARE CHARACTERISTICS

The following is a description of the PCS hardware and its performance requirements. With the exception of the star tracker and the quad sensor, all hardware is expected to be "of the shelf".

5.1 Star tracker Unit (STU)

The STU is required to be of sub-arcsecond accuracy similar to the JPL AST design used in the ASTROS mission. It shall have the capability of locating and tracking up to 4 stars within its Field of View (FOV) of 2" X 2". It must be sensitive to stars of magnitude 10.5 with a noise equivalent angle of the order of 0.16 arcsecond. The STU facilitates initial attitude calibration following deployment and, working together with the IRU and the QS, provides the precision pointing reference. Two STU's are mounted on the observatory external shell opposite to the solar panel. For alignment stability, they are secured to especially designed thermally stable mounting flanges.

5.2 Inertial Reference Unit (IRU)

The IRU is the flight proven NASA standard DRIRU II package consisting of three, two-axis dry rotor mechanical gyros providing redundant incremental position data of up to 0.001 arc second resolution. The bias drift rate stability is 0.003 degrees/hour (3σ) and the scale factor emor of 35 ppm. The IRU is located on the spacecraft in the PCS electronics bay. Gyro data is processed for both internal use and telemetry. This processing accommodates both high and low rate modes, or a combination of modes from each of the three gyro channels.

5.3 Fine Sun Sensors (FSS)

The Fine Sun Sensors consist of a two-axis sensor head and corresponding electronics. It provides a 128° X 128" field of view and is accurate to within 0.5". It provides proportional error signals representing error angle from the sun vector. The FSS is used in initial sun acquisition and to detect pointing constraint violations. A second unit provides redundancy. Figure 8 shows the FSS location.

5.4 Coarse Sun Sensors(CSS)

Coarse Sun Sensors are simple silicon cells which indicate whether or not the sun is present within their 130" X 130" field of view. There are eight (four for redundancy) CSS's located on the spacecraft and, when combined with the FSS they give the Observatory 4π steradians of coverage as shown in Figure 8.

5.4 Quad Sensor (QS)

A cryogenic Quad Sensor (QS) located at the SIRTF focal plane, aligns the telescope LOS with the external fine guidance STU LOS. The alignment information is provided through periodic observations of the same star by both sensors. These co-alignment observations account for the thermal distortion between the external sensor and focal plane. The frequency of alignment is to be determined and is expected to be on the order of a few days. The specifications of the QS are to be determined.

5.5 Pointing Control Electronics (PCE)

The pointing control electronics share a common processor with the C&DH subsystem. It is estimated that the PCS will be required to perform 0.5 MIPS (million instructions per second) and use 205K words of RAM (Random Access Memory). Additionally SK words of ROM (Read only Memory) are needed for safety essential functions. The baseline design assumes no new electronic component development, since most of the of the electronics under development for the Cassini spacecraft will be utilized.

5.6 Reaction Wheel Assemblies (RWA)

Four RWAS are used to provide momentum storage capability needed to maintain SIRTF in an accurate inertial hold attitude and to supply control torque for maneuvering. The wheel-size is chosen to compensate for the adverse effects of worst case environmental torque, wheel speed uncertainties, and the possibility of one failed wheel. Each wheel has an output torque range of 0.00 to ± 0.17 N-m compatible with a speed range of ±4,000 rpm. The four wheels are configured in a tetrahedron with their spin axes at 20” to the base. This strategy provides maximum control authority about the spacecraft transverse axis (Y& Z).

5.7 Reaction Control Subsystem (RCS)

The Reaction Control Subsystem (RCS) consists of twelve thrusters located in four clusters to provide couples about all three axes. Single thrusters are used to provide torque about the Y and Z axis. A couple is used for torque about the X axis, because single thrusters would also impart torque about the Z axis. Couple redundancy is therefore only found about the X-axis.

6 CONCLUSION

Pointing and control requirements have been reviewed and a candidate design has been discussed for the SIRTF observatory. The performance driving requirements are; attitude knowledge to 3 arcsecond, stability to 0.25 arcsecond over 1000 seconds duration, relative repositioning to within 0.25 arcsecond and sky coverage of 99.5%. The challenge of conceiving an affordable PCS design has been met, Key features of the design include, a sub-arcsecond externally located tracker, a DRIRU-II class IRU and quad sensors for boresight and star tracker alignment. Reaction wheels are used for slew maneuvers and a cold gas system is used for momentum dumping.

7 ACKNOWLEDGMENT

This work was performed at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration. The author would like to thank M. G. Osmolovsky for providing the mission figures.

8 REFERENCES

1. J. N. Bahcall et al, “The Decade of Discovery in Astronomy and Astrophysics,“ National Academy Press, Washington, D. C., 1991.

2. M. W. Werner and M. Bothwell, “The SIRTF Mission,” Infrared/Submillimeter Astronomy, COSPAR/World Space Congress, September 1992.

3. J. H, Kwok, P. R. Eisenhardt and M. G. Osmolovsky, “ Using a Solar Orbit for SIRTF," 181st American Astronomical Society Meeting, Phoenix, AZ, January 7,1993.